

Article Information

Received date: Jul 28, 2016

Accepted date: Jul 29, 2016

Published date: Sep 14, 2016

*Corresponding author

Arda Ozyuksel, Department of
Cardiovascular Surgery, Istanbul Medipol
University, Medipol MEGA Hospital,
Turkey; Tel: (90) (212) 4607548; Email:
ozyukselarda@yahoo.com

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Keywords Ventricular Assist Device;
Cardiac Transplantation; Heart Failure;
Extracorporeal Membrane Oxygenation

Review Article

Recent Advances in Surgical Treatment
of Pediatric Heart FailureArda Ozyuksel^{1*}¹Department of Cardiovascular Surgery, Istanbul Medipol University, Medipol MEGA Hospital, Turkey

Abstract

Mechanical circulatory support systems and cardiac transplantation are the two important treatment modalities when pediatric cases with acute or chronic cardiac failure are considered. Although extracorporeal membrane oxygenation is widely used in the treatment of cardiac failure in many cardiac surgery centers, the rates of complications and mortality significantly increase after two weeks of usage. However, the treatment of the patients as a 'bridge to recovery' or 'bridge to transplantation' have become possible by the implementation of these long term devices even in infants. In this text, the mechanical circulatory support systems and pediatric cardiac transplantation will be reviewed. In order to provide the unity of the topics, only the ventricular assist devices, their technical properties and clinical applications will be focused on. The operative and postoperative period of the cardiac transplantation in the pediatric population will be overviewed.

Introduction

Mechanical Circulatory Support Systems (MCCS) are successfully used in the treatment of acute and chronic heart failure. Extracorporeal Membrane Oxygenation (ECMO) is the most frequently used MCCS in the postoperative cardiac failure; however, complication rates significantly increase after the second week of implementation [1]. The mid- and long-term implementations include Intra Aortic Balloon Counter Pulsation (IABP), Ventricular Assist Devices (VAD) and Total Artificial Heart (TAH). Intra aortic balloon counter pulsation has a very limited utility when the pediatric patient population is considered. Today, the most effective treatment option for cardiac failure is Cardiac Transplantation (CTx).

There are Six Targets to Be Addressed When MCCS Is to Be Implemented

Bridge to transplantation

The patients in the waiting list for CTx are included.

Destination therapy

This rare target is the final treatment modalities for the patients who are not candidates for Ctx. Rare examples in the pediatric population include the patients with Duchenne muscular dystrophy [2].

Bridge to recovery

The MCCS is implemented for the period of convalescence from a transient myocardial dysfunction such as colchicum intoxication.

Bridge to decision

The patient is supported until a decision is made whether CTx or destination therapy will be considered.

Bridge to bridge

The patients in whom the short term device support is changed to a long term MCCS are involved under this heading.

Bridge to eligibility

This target includes the patients who become eligible for CTx after a period of MCCS due to the transiently increased pulmonary arterial blood pressure and/or vascular resistance.

Mechanical circulatory support systems have been developed with pioneering efforts by DeBakey in early 1960's [3,4]. On the other hand, the device-patient size mismatch has been encountered as an important problem when the pediatric MCCS are considered. Although the pediatric assist device implementations raised as modifications of adult MCCS, the well-known pediatric VAD, Berlin Heart Excor was approved by US Food and Drug Administration (FDA) in 2011 [5].

Table 1: Properties of the mechanical circulatory support devices implemented in children [12].

Device	Location	Flow	Power Supply	SV (mL) or (rpm)	Flow capacity (L/min)	Body Surface Area (m ²)	Patient Mobilization
Short Term							
Rota Flow	EC	Continuous	EM	0-5000 rpm	0-10	no lower limit	No
Pedi Mag	EC	Continuous	EM	0-5500 rpm	<1.5	<0.5	No
Tandem Heart	EC	Continuous	Electric	3000-7500 rpm	<5	>1.3	No
Uzun Dönem							
Excor	EC	Pulsatile	Pneumatic	10,25,30,50, 60, 80 mL	Variable	0.2-1.3	Yes
Pvad/Ivad	EC/IC	Pulsatile	Pneumatic	65 mL	<7	>0.7	Yes, discharge possible
Heart Ware HVAD	IC	Continuous	EM	2400-3200 rpm	<10	>1	Yes
Heart Mate II	IC	Continuous	Electric	6000-15000 rpm	>2.5	>1.4	Yes, discharge possible

SV: Stroke Volume; **rpm:** Revolution per minute; **EC:** Extra Corporeal, **IC:** Intra corporeal; **PVAD:** Paracorporeal Ventricular Assist Device; **IVAD:** Implantable Ventricular Assist Device; **EM:** Electromagnetic.

Another important mile stone in pediatric MCCS development is the PumpKIN (Pumps for kids, infants and neonates) program which is focused on pediatric MCCS since 2008 [6].

Patient Selection

The common property of all the indications for implementation of MCCS is clinically significant acute or chronic heart failure despite maximal medical treatment. In general, in cases where irreversible organ system damage and active infections are considered, MCCS are contraindicated. There are several exceptions for this general overview, such as treatment of postoperative heart failure and active respiratory infections with ECMO [7]. In cases with prematurity, low birth weight and some types of chromosomal abnormalities, MCCS implementation may be contraindicated [8]. On the other hand, recent reports state that infants with small gestational age have a cardiovascular profile which carries more risk for ventricular dysfunction [9]. Therefore, development of smaller MCSS for implementation in infants with smaller body weight is mandatory in future.

Device Selection

Three types of variables are encountered while selecting an appropriate device for the pediatric patient. The type of support (cardiac or cardiopulmonary), possible duration of the support and the patient size (body surface area). Short term MCCS devices are

described as duration less than 14 days. The most common options are ECMO, Jostra Rota Flow Centrifugal Pump (Maquet Cardiovascular, Wayne, NJ, USA), Thoratec PediMag (Thoratec Co., Pleasanton, CA, USA) and Tandem Heart (Cardiac Assist Inc., Pittsburgh, PA, USA). Long term support devices are Berlin Heart EXCOR (Berlin Inc., Berlin, Germany), Thoratec VAD (IVAD/PVAD; Thoratec Co., Pleasanton, CA, USA), Heart Ware HVAD (Heart Ware Systems, Farmington, MA, USA), Heart Mate-II (Thoratec Co., Pleasanton, CA, USA). (Table 1) summarizes the main technical properties of these MCCS devices [8]. (Figure 1) represents the commonly used ventricular assist devices.

Complications

Probably the most feared complication during the MCCS period is stroke. Stroke may be caused either by embolization or hemorrhage. However, cases with embolic stroke are more commonly encountered, especially in cases where pulsatile devices are used [10]. The MCCS where the hemorrhage may become a major complication is ECMO. On the other hand, infections, renal-hepatic dysfunction, pancreatitis and other complications may be encountered.

Pediatric Cardiac Transplantation

Pediatric CTx has developed since the initial efforts of Dr. Adrian Kantrowitz, who transplanted hearts to infants [11]. Surgical technique, technological developments and more importantly, development of new drugs for immunosuppression had effects on this successful history. More than 11,000 pediatric cardiac transplantations have been performed since 1967 [12]. The transplanted patients are followed up with life-long immunosuppressive treatment. Several complications may be encountered in this follow up period such as coronary allograft vasculopathy, infections and malignancies. A recent paper reports the survival of pediatric CTx as (median) 19.7 years in infants, 16.8 years in 1-5 years of age, 14.5 years in 6-10 years of age and 12.4 years in 11-17 years of age [13]. The mortality rates are the highest at the first postoperative year which steadily decreases afterwards. Acute and chronic rejection are the leading causes of mortality in the early postoperative period, however, coronary allograft vasculopathy is responsible for most of the mortalities in the following years. The etiology of coronary allograft vasculopathy is thought to be multifactorial including viral infections, hypertension, rejection episodes, hyperlipidemia and secondary diabetes mellitus.



Result

Although the gold standard treatment option for end-stage pediatric heart failure is cardiac transplantation, mechanical circulatory support systems are deemed mandatory both for prolonging the lives of the selected patients in the waiting list and for the ones who are not eligible for transplantation.

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